

**WHAT IS CLAIMED IS:**

1. A timing extractor for extracting a timing component for determining a symbol from a digital modulated signal having a symbol rate  $f_s$ , comprising:

5 a frequency converting means for converting positive and negative frequency components of  $f_s/2$  included in a complex baseband signal to a frequency position  $f_m$  ( $0 < |f_m| < f_s/2$ ), the complex baseband signal being obtained from the digital modulated signal and formed from an I signal and a Q signal;

a nonlinear processing means for at least squaring the I signal and the Q signal resulting from frequency conversion by the frequency converting means; and

10 a frequency extracting means for extracting from an output signal of the nonlinear processing means a frequency component  $2f_m$ , i.e., a frequency component which is twice the frequency position  $f_m$ , and outputting the extracted frequency component as a timing signal.

15 2. The timing extractor according to claim 1, wherein the frequency position  $f_m$  is  $|f_m| = f_s/2M$  (where  $M$  is an integer of at least two).

3. The timing extractor according to claim 2, wherein  $M = 2$  and the frequency position  $f_m$  is  $|f_m| = f_s/4$ .

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4. The timing extractor according to claim 2, wherein  $M = 4$  and the frequency position  $f_m$  is  $|f_m| = f_s/8$ .

5. The timing extractor according to claim 1 or 2, wherein the frequency converting

means includes a filtering means for removing in advance from the complex baseband signal a frequency component which will become an aliasing distortion component for the frequency component  $2f_m$  included in the output signal of the nonlinear processing means.

5           6. The timing extractor according to claim 1, wherein the frequency converting means includes a first frequency shifting means for shifting a frequency of the complex baseband signal in a frequency increasing direction, and a second frequency shifting means for shifting a frequency of the complex baseband signal in a frequency decreasing direction.

10           7. The timing extractor according to claim 1, 2 or 6, wherein the frequency converting means includes a frequency shifting means for shifting a frequency of the complex baseband signal in a frequency increasing direction and a frequency decreasing direction by  $f_s/2$ .

15           8. The timing extractor according to claim 1, wherein the frequency converting means includes a bandpass filtering means for extracting the positive and negative frequency components of  $f_s/2$  included in the complex baseband signal.

20           9. The timing extractor according to claim 3, wherein the frequency converting means includes a numerical operation means for calculating upon every two samplings a true value multiplied by  $\sqrt{2}$  as the positive and negative frequency components of  $f_s/2$  converted to the frequency position  $f_m$ .

10. The timing extractor according to claim 9, wherein the nonlinear processing

means includes two multiplying means for squaring the I signal and the Q signal resulting from frequency conversion by the frequency converting means, respectively, an adder for adding the I and Q signals squared by the multiplying means, a bit shifting means for multiplying an output of the adder by 1/2, and a selecting means for selecting the output of the adder or an output of the bit shifting means.

11. The timing extractor according to claim 1 or 2, wherein the frequency extracting means outputs the timing signal once every L times when the frequency position  $f_m$  is  $|f_m| = f_s/(2^2 \times L)$  (where L is an integer of at least one).

12. The timing extractor according to claim 6, wherein the first and second frequency shifting means each includes a filtering means for removing in advance an interference component which is present in the frequency position  $f_m$ .

13. The timing extractor according to claim 6, wherein the frequency converting means complex adds respective outputs of the first and second frequency shifting means.

14. A method for extracting a timing component for determining a symbol from a digital modulated signal having a symbol rate  $f_s$ , comprising the steps of:

converting positive and negative frequency components of  $f_s/2$  included in a complex baseband signal to a frequency position  $f_m$  ( $0 < |f_m| < f_s/2$ ), the complex baseband signal being obtained from the digital modulated signal and formed from an I signal and a Q signal;

at least squaring the I signal and the Q signal resulting from the frequency

conversion;

adding the squared I and Q signals; and

extracting from the added signal a frequency component  $2f_m$ , i.e., a frequency component which is twice the frequency position  $f_m$ , as a timing signal.

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15. The method according to claim 14, wherein the frequency position  $f_m$  is  $|f_m| = f_s/2M$  (where  $M$  is an integer of at least two).

16. A demodulator, comprising:

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an antenna for receiving a digital modulated signal;

a semi-synchronous wave detecting means for quadrature-detecting the digital modulated signal received by the antenna to obtain a complex baseband signal formed from an I signal and a Q signal;

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an A-to-D converting means for converting the complex baseband signal obtained by the semi-synchronous wave detecting means from analog to digital values; and

the timing extractor according to claim 1, wherein

the digital complex baseband signal obtained by the A-to-D converting means is sampled at a sampling frequency  $2f_s$  based on a timing signal from the timing extractor, whereby demodulated data is obtained.